

## NANOPARTICLES IN SUBSURFACE ENVIRONMENTS: ABUNDANCE AND TRANSPORT OF THE MOBILE FRACTION

Jiamin Wan, Guilin Han, Jasquelin Pena, Xiang-Yun Song, and Tetsu Tokunaga  
Contact: Jiamin Wan, 510/486-6004, [jmwan@lbl.gov](mailto:jmwan@lbl.gov)

### RESEARCH OBJECTIVES

The earth science community has identified environmental nanoscience as an important emerging field. This project provides the first survey of mobile nanoparticle inventories for sediments from a variety of subsurface environments. The research will also provide systematic studies of subsurface nanoparticle transport and its dependence on nanoparticle, sediment, solution, and hydraulic characteristics.

### APPROACH

Quantification of the potentially mobile nanoparticle inventory requires separation of nanoparticle size fractions. In this study, particles in the <100 nm size range are defined as nanoparticles. Methods such as flow-through columns, batch extractions in water, and batch extractions with a dispersant (sodium hexametaphosphate) are used. In these ways, operationally defined measures of mass and specific surface areas associated with different particle fractions will be obtained in several sediment types from DOE facilities across the country. Nanoparticle transport quantification will be performed through laboratory column experiments with three types of variables. These are (1) natural versus synthetic (glass bead) sediments, (2) natural versus synthetic (polystyrene latex) particles, and saturated versus unsaturated conditions. Through these experiments, the validity of filtration-theory predictions for nanoparticles will be tested.

### ACCOMPLISHMENTS

Mobile nanoparticle inventories for two types of sediments were studied, one from the Hanford Site and another from Oak Ridge National Laboratory. Our results show that the release of mobile nanoparticles depends strongly on solution chemistry, including pH, ionic strength, and anions. The maximum particle release occurred at the lowest ionic strength condition. Alkaline pH favors particle release. For example, in the Oak Ridge sediments, the measured nanoparticle fractions (<0.1  $\mu\text{m}$ ) were 0.98% at pH 12.0, and the maximum release obtained with hexametaphosphate solution was 1.72%. The nanoparticle fraction is about 7% of the total clay fraction (<2.0  $\mu\text{m}$ ) released in this sediment. We have also discovered that some U(VI) nanoparticles are relatively stable in the pore solutions of contaminated Hanford sediment (as shown in Figure 1). Uranium(IV) nanoparticles have been found in the mine drainage waters as a result of microbial reduction. This species has previously been considered highly soluble under our test

conditions, and thus we did not expect to find U(VI) nanoparticles in this contaminated Hanford system.

### SIGNIFICANCE OF FINDINGS

This research provides the first survey of mobile nanoparticle inventories for sediments from a variety of subsurface environments. It will also provide systematic studies of subsurface nanoparticle transport and its dependence on nanoparticle, sediment, solution, and hydraulic characteristics. The transport experiments will also be the first to test the validity of filtration theory for nanoparticles in the subsurface.

### RELATED PUBLICATIONS

Wan, J., G. Han, J. Pena, X.Y. Song, and T.K. Tokunaga, The natural abundance of nanoparticles in soils. *J. Colloid Interface Sci.*, 2003 (submitted).

Wan, J., J. Pena, X.Y. Song, Z. Zheng, and T.K. Tokunaga, U(VI) nanoparticles in calcium carbonate-rich subsurface environment. *Environ. Sci. Technol.*, 2003 (submitted).

### ACKNOWLEDGMENTS

This project is supported by the Director, Office of Science, Office of Basic Energy Sciences, Division of Chemical Sciences, Geosciences, and Biosciences, of the U.S. Department of Energy under Contract No. DE-AC03-76-SF00098.

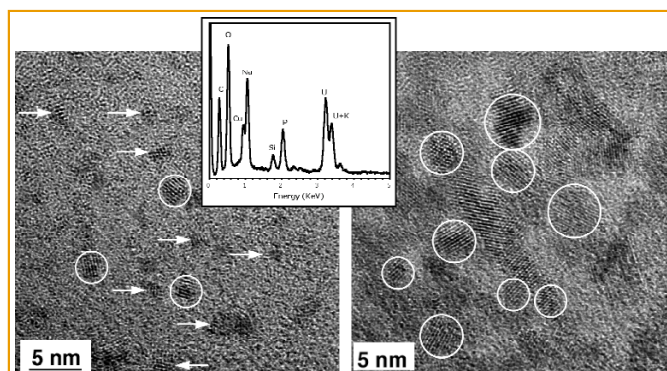


Figure 1. U(VI) nanoparticles (marked by arrows and circles) obtained from a pore solution of U contaminated sediment. Based on lattice fringe (by TEM) and elemental composition (by EDX) analyses, the particles are identified as sodium uranium oxide phosphate hydrate,  $\text{Na}_4\text{U}_3\text{O}_8(\text{PO}_4)\cdot 6\text{H}_2\text{O}$  (Wan et al., unpublished).